CERTIFICATION OF TRANSLATION

I, ***Joo-hyun Hong***, an employee of Y.P. LEE, MOCK & PARTNERS of The Goryo Bldg., 1575-1 Seocho-dong, Seocho-gu, Seoul, Republic of Korea, hereby declare under penalty of perjury that I understand the Korean language and the English language; that I am fully capable of translating from Korean to English and vice versa; and that, to the best of my knowledge and belief, the statement in the English language in the attached translation of ***Korean Patent Application No. 10-2003-0027992*** consisting of 20 pages, have the same meanings as the statements in the Korean language in the original document, a copy of which I have examined.

Signed this 18th day of May 2007

Hong Joo Hyun

ABSTRACT

[Abstract of the Disclosure]

Provided is a flat panel display including thin film transistors (TFT) having excellent characteristics without changing the size of active layers of the TFT and improved circuit characteristics and increased resolution. The flat panel display includes a pixel area comprising a light emitting device and at least one pixel unit TFT comprising a semiconductor active layer including at least channel areas; and a circuit area comprising at least one circuit unit TFT controlling signals applied to the pixel area and having a semiconductor active layer including at least channel areas, wherein the thicknesses of the channel areas at least of the pixel unit TFT and the circuit unit TFT are different from each other.

[Representative Drawing]

FIG. 3

SPECIFICATION

[Title of the Invention]

Flat panel display with TFT

[Brief Description of the Drawings]

FIG. 1 is a plane view of an active matrix type electroluminescence display device according to an embodiment of the present invention;

FIG. 2 is a plane view of crystallized structures of an active layer of a circuit unit thin film transistor (TFT) and an active layer of a pixel unit TFT;

FIG. 3 is a cross-sectional view of different thicknesses of the active layer of a circuit unit TFT and the active layer of a pixel unit TFT in line I-I direction in FIG. 2;

FIG. 4 is a graph of a relation between a size of a crystal grain and a current mobility;

FIG. 5 is a graph of a relation between an energy density and a size of a crystal grain in an excimer laser annealing (ELA) method;

FIG. 6 is a cross-sectional view of an example of a circuit unit TFT; and

FIG. 7 is a cross-sectional view of an example of a pixel unit TFT.

[Detailed Description of the Invention]

[Object of the Invention]

[Technical Field of the Invention and Related Art prior to the Invention]

The present invention relates to an active matrix type flat panel display including a thin film transistor (TFT), and more particularly, to a flat panel display including a TFT having a polycrystalline silicon as an active layer, and channel areas of the active layers in a circuit unit TFT and a pixel unit TFT having different thickness and crystal grains of different sizes from each other.

A thin film transistor (TFT) in a flat display device such as a liquid display device, an organic electroluminescence display device, or an inorganic electroluminescence display device is used as a driving device for controlling operations of pixels and a driving device for driving the pixels.

The TFT includes a semiconductor active layer having a drain area and a source area doped with impurities of high concentration and a channel area formed between the drain area and the source area, a gate insulating layer formed on the semiconductor active layer, and a gate electrode formed on the gate insulating layer which is located on an upper part of the channel areas of the active layer. The semiconductor active layer can be classified into an amorphous silicon and polycrystalline silicon according to crystallized status of the silicon.

The TFT using the amorphous silicon has an advantage in that a deposition can be performed at a low temperature, however, it also has disadvantages in that an electrical property and a reliability of the TFT are degraded and it is difficult to make the display device be a larger area. Thus, the polycrystalline silicon is mainly used recently. The polycrystalline silicon has a higher mobility of tens of - hundreds of $cm^2/V.s$, and low high frequency operation property and leakage current value, thereby it is suitable to be used in the flat panel display of high resolution and larger area.

Meanwhile, the TFT as described above is used as a pixel unit TFT such as a switching device or a pixel driving device and as a circuit unit TFT in circuit areas for driving the pixel unit TFT in a flat panel display

An organic electroluminescence display device, which is a type of flat panel displays, uses an organic electroluminescence device (hereinafter referred to as "organic EL device"). The organic EL device has an emission layer made of an organic material between an anode electrode and a cathode electrode. In the organic EL device, when a positive voltage and a negative voltage are respectively applied to the electrodes, holes injected from the anode electrode are moved to the emission layer through a hole transport layer, and electrons are injected into the emission layer through an electron transport layer from the cathode electrode. The holes and electrons are

recombined on the emission layer to produce exitons. The exitons are changed from an excited status to a ground status, and accordingly, phosphor molecules of emission layer are radiated to form an image. In case of a full-color electroluminescence display, pixels radiating red (R), green (G), and blue (B) colors are disposed as the organic EL devices to realize the full colors.

In the active matrix type organic electroluminescence display device (AMOLED), a panel with high resolution is required, however, the above described TFT formed using the polycrystalline silicon of high function causes some problems in this case.

That is, in the active matrix type flat panel display device such as the active matrix type organic electroluminescence display device, the circuit unit TFT and the pixel unit TFT are made of the polycrystalline silicon, thus, the two TFTs have the same current mobility. Therefore, switching properties of the circuit unit TFT and low current driving properties of the pixel unit TFT cannot be satisfied simultaneously. That is, in case where the pixel unit TFT and the circuit unit TFT of high resolution display device are fabricated using the polycrystalline silicon having larger current mobility, the high switching property of the circuit unit TFT can be obtained, however, a brightness becomes too high since a current flowing toward an electroluminescence (EL) device through the pixel unit TFT increases, thus increasing a current density per unit area and decreasing a life time of the EL device.

On the other hand, in case where the circuit unit TFT and the pixel unit TFT of the display device are fabricated using the amorphous silicon having the low current mobility, the TFTs should be fabricated in such way that the pixel unit TFT uses a small current and the circuit unit TFT uses a large current.

To solve the above problems, methods for restricting current flowing through the pixel unit TFT are provided, such as a method for increasing resistance of a channel area by reducing a ratio of a length for a width of the pixel unit TFT (W/L) and a method for increasing resistance by forming a low doped area on the source/drain areas of the pixel unit TFT.

However, in the method decreasing the W/L by increasing the length, a length of the channel areas increases, thus forming stripes on the channel areas and reducing an aperture area in a crystallization process in an excimer laser annealing (ELA) method. The method decreasing W/L by reducing the width is limited by a design rule of a photolithography process, and it is difficult to ensure a reliability of the TFT.

Also, the method for increasing the resistance by forming the low doped area requires an additional doping process.

[Technical Goal of the Invention]

The present invention provides as flat panel display including a thin film transistor (TFT) having excellent characteristics without changing the size of an active layer of the TFT.

The present invention also provides a flat panel display having improved circuit properties and resolution.

[Structure and Operation of the Invention]

According to an aspect of the present invention, there is provided a flat panel display comprising: a pixel area comprising a light emitting device and at least one pixel unit thin film transistor (TFT) comprising a semiconductor active layer including at least channel areas; and a circuit area comprising a circuit unit TFT controlling signals applied to the pixel area and having a semiconductor active layer including at least channel areas, wherein the thicknesses of the channel areas at least of the pixel unit TFT and the circuit unit TFT are different from each other.

The channel areas of one of the circuit unit TFT and the pixel unit TFT that requires greater current mobility may be formed to be thinner.

The at least channel areas of the circuit unit TFT may be thinner than the at least channel areas of the pixel unit TFT.

The at least channel areas of the circuit unit TFT may be thinner than the channel area of a pixel unit TFT driving the light emitting device by allowing

predetermined current to flow through the light emitting device according to data signals in the pixel unit TFT.

The thickness of the channel areas of the TFT requiring large current mobility between the pixel unit TFT and the circuit unit TFT may be in a range of 300 – 800 Å, and the thickness of the TFT requiring small current mobility between the pixel unit TFT and the circuit unit TFT may be in a range of 500 – 1500 Å.

The thickness of the at least channel areas of the circuit unit TFT may be 300 – 800 Å.

The at least channel areas of the pixel unit TFT may be 500 – 1500 Å.

The semiconductor active layer may be formed of polycrystalline silicon, and the size of the crystal grain of the at least channel areas of the circuit unit TFT and the size of the crystal grain of the at least channel areas of the pixel unit TFT may be different from each other.

The size of the crystal grain of the channel areas of the circuit unit TFT may be larger than the size of the crystal grain of the pixel unit TFT.

The size of the crystal grain of the channel areas of the circuit unit TFT may be larger than the size of the crystal grain of the at least channel areas of a pixel unit TFT driving the light emitting device by allowing predetermined current to flow through the light emitting device according to data signals in the pixel unit TFT.

The polycrystalline silicon may be formed in a crystallization method using a laser.

The at least channel areas of the circuit unit TFT and the channel areas of the pixel unit TFT may be formed simultaneously by irradiating the laser.

Preferred embodiments of the present invention will now be described with reference to the attached drawings.

FIG. 1 is a plane view of an active matrix type organic electroluminescence display device, which is a type of a flat panel display according to the present invention, according to an embodiment of the present invention. Referring to FIG. 1, the organic

electroluminescence device includes a pixel area 20, and a circuit area 10 at the edge of the pixel area 20.

The pixel area 20 includes a plurality of pixels, and each of the pixels are formed of a plurality of sub-pixels respectively including an organic electroluminescence device. In the case of a full color organic electroluminescence device, the sub-pixels of red (R), green (G), and blue (B) colors can be arranged in various patterns such as a line pattern, a mosaic pattern, or a grid type pattern to construct the pixel. Also, a mono color flat panel display can be used instead of a full-color flat panel display shown in FIG. 1.

The circuit area 10 connects to power for driving the pixel area 20 and controls image signals input to the pixel area 20.

In the above described organic electroluminescence device, the pixel area 20 and the circuit area 10 may respectively include at least one TFT.

A TFT installed in the pixel area 20 may be a pixel unit TFT such as a switching TFT transmitting data signals to the light emitting device according to signals of a gate line to control the operation of the light emitting device, and a driving TFT driving the switching TFT such that predetermined current flows through the organic electroluminescence light emitting device according to the data signals. A TFT installed in the circuit area 10 may be a circuit unit TFT provided to realize a predetermined circuit.

The number of TFTs and arrangement of TFTs such as the circuit unit TFT and the pixel unit TFT can be varied from properties of the display device and a driving method of the display device.

The circuit unit TFT 10 and the pixel unit TFT 20 respectively include semiconductor active layers respectively formed of amorphous silicon or polycrystalline silicon, and the semiconductor active layers include predetermined channel areas. The channel areas are the areas located on center portions of the source region and the drain region and corresponds to a region that is formed by the gate electrode being insulated in upper portions thereof.

FIG. 2 is a plane view of crystallized structures of an active layer of a circuit unit TFT and an active layer of a pixel unit TFT, and FIG. 3 is a cross-sectional view thereof.

As can be seen in FIG. 2, an active layer 12 of the circuit unit TFT and an active layer 22 of the pixel unit TFT respectively include a channel area C1 and a channel area C2 in center portions thereof.

The active layers 12 and 22 can be formed to have different thicknesses from each other as illustrated in FIG. 3. That is, a thickness d1 of the active layer 12 of the circuit unit TFT is formed to be less than a thickness d2 of the active layer 22 of the pixel unit TFT. It is sufficient when the channel areas C1 and C2 of the active layers 12 and 22, which are the center portions, have different thicknesses, but due to the complexity of structure designing, the entire thicknesses of the active layer 12 of the circuit unit TFT and the active layer 22 of the pixel unit TFT are formed to be different from each other.

Meanwhile, the changes in the thicknesses of the at least channel areas of the active layers are determined by the current mobility in each of the channel areas. That is, the at least channel areas of the active layer of the TFT that requires a greater current mobility among the circuit unit TFT and the pixel unit TFT is formed thinner than the at least channel areas of the active layer of the TFT that requires a smaller current mobility.

This is because when the thickness of the at least channel areas is small, the current mobility in the channel areas increases, and thus more excellent TFT characteristics can be obtained. Accordingly, when the thickness of the at least channel areas of the active layer of the TFT that requires a greater current mobility than usual is formed to be small, more excellent TFT characteristics can be obtained.

However, in general, the circuit unit TFT requires higher response characteristics and the pixel unit TFT requires more uniformity rather than response characteristic.

Accordingly, according to an embodiment of the present invention, as illustrated in FIG. 3, TFTs having high response characteristics in the circuit unit can be provided by forming the thickness d1 of the active layer 12 of the circuit unit TFT is to be smaller

than the thickness d2 of the active layer 22 of the pixel unit TFT. This applies not only to the active layers formed of polycrystalline silicon but also to active layers formed of amorphous silicon.

The pixel unit TFT includes a switching TFT transmitting data signals and a driving TFT directly driving a light emitting device. Since the switching TFT performs switching, it requires higher response characteristics than the driving TFT, and the driving TFT require higher uniformity rather than response characteristic, for example, for the purpose of realizing high resolution.

Accordingly, according to the current embodiment of the present invention, the at least channel areas of the active layer of the circuit unit TFT may be preferably formed to be thinner than the at least channel areas of the active layer of the driving TFT of the pixel unit TFT.

Meanwhile, as the active layer 12 of the circuit unit TFT and the active layer 22 of the pixel unit TFT are formed to have different thicknesses from each other, when crystallizing from amorphous silicon to polycrystalline silicon, the size of the crystals can be differentiated, and thus the current mobility can also be differentiated. Furthermore, the size of the crystals can be adjusted without an additional process; for example, in a crystallization method using an ELA method, active layers having different crystal sizes can be obtained by simultaneously irradiating laser onto two different regions.

The crystal size of the at least channel areas of the active layer of the TFT that requires higher current mobility among the circuit unit TFT and the pixel unit TFT may be preferably greater. This is because when the crystal size of the active layer is large, the current mobility is also large in the channel areas according to the crystal size.

Regarding the size of the crystal grain and the difference in the current mobility according to the size of the crystal grain, as illustrated in FIG. 4, as the size of the crystal grain increases, the current mobility also increases, and thus the graph shows an almost linear relationship.

Accordingly, in the embodiment of the present invention as illustrated in FIG. 2, the size of the crystal grain of the channel areas of the active layer of the TFT that

requires greater current mobility, that is, the circuit unit TFT, is formed to be greater than the size of the crystal grain of the channel areas of the active layer of the TFT that requires a smaller current mobility than the circuit unit TFT, that is, the pixel unit TFT.

Meanwhile, as described above, the switching TFT requires higher response characteristics than the driving TFT, and the driving TFT requires higher uniformity rather than response characteristic, for example, for the purpose of realizing high resolution. Thus the size of the crystal grain of the at least channel areas of the active layer of the circuit unit TFT may be preferably formed to be larger than that of the at least channel areas of the active layer of the driving TFT in the pixel unit TFT.

The size of the crystal grain can be made differently by differentiating the thickness of each of the active layers as illustrated in FIG. 3.

In other words, as described above, when the thickness d1 of the active layer 12 of the circuit unit TFT is formed to be less than the thickness d2 of the active layer 22 of the pixel unit TFT, the energy density of the laser the thinner amorphous silicon receives becomes greater, and thus a larger crystal grain can be obtained. The size of the crystal grain according to the energy density of the laser the amorphous silicon receives can be determined according to the relation illustrated in FIG. 5. FIG. 5 illustrates the differences in the size of the crystal grain according to the energy density of the irradiated laser when the amorphous silicon thin layer having a thickness of 500 Å is crystallized in an ELA method. However, when the amorphous silicon thin layer is irradiated by laser having too great energy density, the amorphous silicon thin layer is melted and the size of the crystal grain may become rather smaller. Accordingly, the silicon thin layer, from which the active layer 12 of the circuit unit TFT that requires greater crystal grain is to be formed, should not be formed too thin.

According to an embodiment of the present invention, the thickness d1 of the silicon thin layer from which an active layer of the TFT that requires greater current mobility, that is, the active layer 12 of the circuit unit TFT, is to be formed, may be 300 to 800 Å, and the thickness d2 of silicon thin layer from which an active layer of the TFT which requires lower current mobility, that is, the active layer 22 of the pixel unit TFT, is

to be formed, may be 500 to 1500 Å. The differences in the thicknesses of the silicon thin layer can be made by photo-lithography that is well known in the art. The thicknesses of the amorphous silicon thin layers that are being pattered are controlled by controlling the light transmittivity of an optical mask with respect to an area in which an active layer of the circuit unit TFT is to be formed and an area in which an active layer of the pixel unit TFT is to be formed.

According to the present invention, the size of the crystal grain can be made differently by simultaneously irradiating laser using the differences in the thicknesses, thereby simplifying the manufacturing process.

Meanwhile, the above described circuit unit TFT and the pixel unit TFT may have structures as illustrated in FIGS. 6 and 7.

First, as shown in FIGS. 6 and 7, a buffer layer 2 is formed on an insulating substrate 1 of glass material. The buffer layer 2 can be formed using SiO_2 and can be deposited in a plasma enhanced chemical vapor deposition (PECVD) method, an atmospheric pressure chemical vapor deposition (APCVD) method, a low pressure chemical vapor deposition (LPCVD) method, or an electron cyclotron resonance (ECR) method. Also, the buffer layer 2 can be deposited to have a thickness of about 3000 Å.

As shown in FIG. 6, a circuit unit TFT 11 includes the active layer 12 on the buffer layer 2, and a gate insulating layer 13 is formed of, for example, SiO2. The active layer 12 may be formed of amorphous silicon or polycrystalline silicon, and the thickness d1 thereof may be 300 to 800 Å as illustrated in FIG. 3 as described above.

An interlayer insulating layer 15 is formed on a gate electrode 14 and a contact hole is perforated in the interlayer insulating layer 15 so that a source electrode 17 and a drain electrode 18 are formed to respectively contact the source and drain regions of the active layer 12 that is doped with a P type or an N type impurity, and then a planarized layer 19 is formed of, for example, acryl, and thus the circuit unit TFT 11 is formed.

The circuit unit TFT can be formed of, as described above, a driving TFT and a switching TFT, and the driving TFT is as illustrated in FIG. 7.

The circuit unit TFT 11 as shown in FIG. 7, particularly, the driving TFT includes, as described above, the active layer 22 on the buffer layer 2, and a gate insulating layer 23 and a gate electrode 24 are formed on the active layer 22. Then, the thickness d2 of the active layer 22 may be, as described above, 500 to 1500 Å.

A first insulating layer 25 is formed on the gate electrode 24, and a first electrode 31 is formed of ITO in a predetermined pattern on the first insulating layer 25. The first electrode 31 can be an anode electrode of the organic EL device 30 which is the light emitting device.

A second insulating layer 26 is formed after the first electrode 31 is formed, and contact holes are perforated so that a source electrode 27 and a drain electrode 28 contact the source and drain regions of the active layer 22 that are doped with N type or P type impurity, and then a planarized layer 29 is formed on the source electrode 27 and the drain electrode 28.

The planarized layer 29 and the second insulating layer 26 are patterned so that the first electrode 31 is exposed, and an organic layer 32 including an organic light emitting layer is formed on the exposed first electrode 31.

The organic layer 32 may use a low molecular organic layer or a high molecular organic layer. In case where the low molecular organic layer is used, a hole injection layer, a hole transfer layer, an organic emission layer, an electron transfer layer, and an electron injection layer may be formed by being stacked in a single or a combination structure. Also, various organic materials such as copper phthalocyanine (CuPc), N,N-Di(naphthalene-1-yl)-N,N'-diphenyl-benzidine (NPB), and tris-8-hydroxyquilnoline aluminum (Alq3) can be used. The low molecular organic layer is formed in a vacuum evaporation method.

The high molecular organic layer may include the hole transfer layer and an emission layer. Here, the hole transfer layer is formed using poly(3,4-ethylenedioxythiophene (PEDOT), and the emission layer is formed using a high molecular organic material such as poly-phenylenevinylene (PPV)-based material

or polyfluorene-based material in a screen printing method or in an inkjet printing method.

Meanwhile, when the active layers 12 and 22 are formed of polycrystalline silicon, amorphous silicon is formed first, and then the active layer of the circuit unit TFT and the active layer of the pixel unit TFT are patterned together by photo-lithograpy. During the patterning process, differences in the thicknesses of the active layers can be made by differentiating the amount of light transmitting through the optical mask. Then, after forming the thicknesses differently, laser is irradiated using the ELA method to make difference in the energy density with respect to the circuit unit and the pixel unit, and accordingly, the size of the crystal grain can be varied.

The TFT can also be formed in various ways and the structures of the TFT can be applied in various ways.

Also, in above descriptions, the present invention is applied to the organic electroluminescence display device, however, the scope of the present invention is not limited thereto. The TFT according to the present invention can be applied to any display devices such as a liquid crystal display (LCD), and inorganic electroluminescence display devices.

[Effect of the Invention]

As described above, according to the present invention, following effects can be obtained.

First, the characteristics of the circuit unit TFT can be improved while including active layers having the same size without changing the size of the active layers of the TFT or changing the driving voltage.

Second, a structure suitable for high resolution can be obtained by increasing the uniformity of the active layer of the pixel unit TFT.

Third, excellent response properties and high resolution can be realized simply by controlling the thickness of the active layers.

Fourth, since the thicknesses of the polycrystalline silicon thin layer are different from each other, structures of crystal grain having different sizes can be obtained by

irradiating laser one time, and thus differences in the current mobility of the channel areas of the active layers of the circuit unit TFT and the pixel unit TFT can be made.

Fifth, uniform brightness can be obtained simply from the crystalline structure of the TFT, and decrease in the life span can be prevented.

Sixth, since the length L of the pixel unit TFT does not have to be increased, decrease in the aperture rate is not caused.

Seventh, the width W of the pixel unit TFT does not have to be reduced, and thus reliability can be improved.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. A flat panel display comprising:

a pixel area comprising a light emitting device and at least one pixel unit thin film transistor (TFT) comprising a semiconductor active layer including at least channel areas; and

a circuit area comprising at least one circuit unit TFT controlling signals applied to the pixel area and having a semiconductor active layer including at least channel areas,

wherein the thicknesses of the channel areas at least of the pixel unit TFT and the circuit unit TFT are different from each other.

2. The flat panel display of claim 1, wherein the channel areas of a TFT that requires greater current mobility among the circuit unit TFT and the pixel unit TFT is formed to be thinner.

3. The flat panel display of claim 1, wherein the at least channel areas of the circuit unit TFT is thinner than the at least channel areas of the pixel unit TFT.

4. The flat panel display of claim 1, wherein the at least channel areas of the circuit unit TFT is thinner than that of a pixel unit TFT driving the light emitting device by allowing predetermined current to flow through the light emitting device according to data signals in the pixel unit TFT.

5. The flat panel display of claim 1, wherein the thickness of the channel areas of the TFT requiring larger current mobility between the pixel unit TFT and the circuit unit TFT is in a range of 300 – 800 Å, and the thickness of the TFT requiring smaller current mobility between the pixel unit TFT and the circuit unit TFT is in a range of 500 – 1500 Å.

6. The flat panel display of claim 1, wherein the thickness of the at least channel areas of the circuit unit TFT is 300 – 800 Å.

7. The flat panel display of claim 1, wherein the thickness of the at least channel areas of the pixel unit TFT is 500 – 1500 Å.

8. The flat panel display of one of claims 1 through 7, wherein the semiconductor active layer is formed of polycrystalline silicon, and the size of the crystal grain of the at least channel areas of the circuit unit TFT and the size of the crystal grain of the at least channel areas of the pixel unit TFT are different from each other.

9. The flat panel display of claim 8, wherein the size of the crystal grain of the channel areas of the circuit unit TFT is larger than the size of the crystal grain of the pixel unit TFT.

10. The flat panel display of claim 9, wherein the size of the crystal grain of the channel areas of the circuit unit TFT is larger than the size of the crystal grain of the at least channel areas of a pixel unit TFT driving the light emitting device by allowing predetermined current to flow through the light emitting device according to data signals in the pixel unit TFT.

11. The flat panel display of claim 8, wherein the polycrystalline silicon is formed in a crystallization method using a laser.

12. The flat panel display of claim 11, wherein the at least channel areas of the circuit unit TFT and the channel areas of the pixel unit TFT are formed simultaneously by irradiating the laser.

FIG. 1

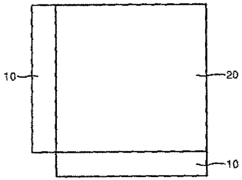


FIG. 2

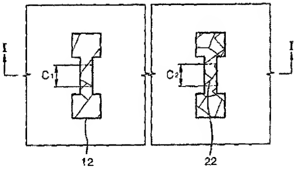


FIG. 3

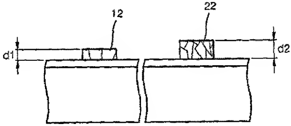

12
22
d1
d2

FIG. 4

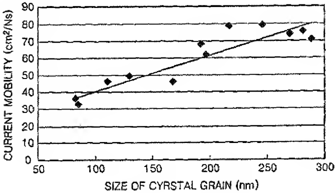
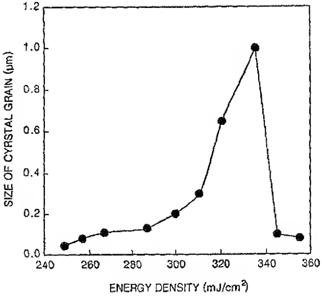
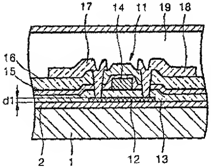

CURRENT MOBILITY (cm²/Ns)
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300
SIZE OF CYRSTAL GRAIN (nm)

FIG. 5



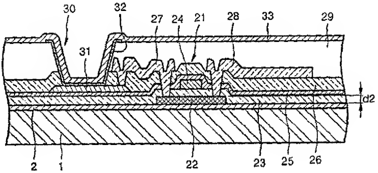
1.2
1.0
0.8
0.6
0.4
0.2
0.0
SIZE OF CYRSTAL GRAIN (μm)
240
260
280
300
320
340
360
ENERGY DENSITY (mJ/cm²)

FIG. 6



17
14
11
19
18
16
15
d1
2
1
12
13

FIG. 7



30
32
27
24
21
28
33
29
31
d2
2
1
22
23
25
26